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EDGE DELAMINATION of COMPOSITE LAMINATES SUBJECT to COMBINED TENSION and TORSIONAL LOADING

by

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Delamination is a common failure mode of laminated composite materials. This type of failure occurs at the free edges of laminates where singular interlaminar stresses are developed due to the difference in Poisson's ratios between the adjacent plies. Typically the delaminations develop next to a 90 degree ply. Edge delamination is important since it results in reduced stiffness and strength of the laminate. The tension/torsion load condition is of particular significance to the structural integrity of composite helicopter rotor systems. Material coupons can easily be tested under this type of loading in servo-hydraulic tension/torsion test stands using techniques very similar to those used for the Edge Delamination Tensile Test (EDT) delamination specimen.

Edge delamination of specimens loaded in tension has been successfully analyzed by several investigators using both classical laminate theory and quasi-three-dimensional (Q3D) finite element techniques. The former analysis technique can be used to predict the total strain energy release rate, while the latter technique enables the calculation of the mixed-mode strain energy release rates. The Q3D analysis is very efficient since it produces a three-dimensional solution on a two-dimensional domain. Some investigators have attempted to employ this technique to analyze the torsion problem as well. Unfortunately, these formulations violate the natural boudary conditions on the free edges of the specimen, thus a full three-dimensional solution is required.

Preliminary tests indicate that delamination under pure torsion loading is associated with angle cracks in the 90 degree plies. These matrix cracks probably form due to tensile failure of the matrix material. Delaminations subsequently form due to the singularities which exist at the ends of these cracks. These delaminations then grow in both the length-wise and width-wise directions. The matrix crack/delamination geometry on one free edge is antisymmetric to the geometry on the opposite free edge. Thus a full 3-d finite element model is required analyze this specimen.

A computer program was developed which generates PATRAN commands to generate this finite element model. PATRAN is a pre- and post-processor which is commonly used with a variety of finite element programs such as MSC/NASTRAN. The program written at NASA LRC creates a sufficiently dense mesh at the delamination crack tips to support a mixed-mode fracture mechanics analysis. The program creates a coarse mesh in those regions where the gradients in the stress field are low (away from the delamination regions). A transition mesh is defined between these regions. This program is capable of generating a mesh for an arbitrarily oriented matrix crack. This program significantly reduces the modeling time required to generate these finite element meshes, thus providing a realistic tool with which to investigate the tension torsion problem.